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CHAPTER 7

The Representation of Information in Long-Term Memory (Part I)

APPLICATION: **Shooting Hoops and Studying**

DISTINCTION BETWEEN PROCEDURAL AND DECLARATIVE KNOWLEDGE
- *ACT Theory's Proposed Distinction*
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APPLICATION: Shooting Hoops and Studying

Alan leaves biology lab at 5 o'clock and walks with his friend, Stan, to the bike rack outside the science building. After discussing whether material covered in the afternoon's lab is likely to be included on the upcoming unit exam, Alan unlocks his bike and rides the three miles to his home. Alan is greeted at home by his younger brother, Joseph, who asks Alan if he would like to play basketball. For the next hour, Alan plays a fast-paced game of one-on-one before showering and settling into the study to begin his preparation for the biology exam.

During Alan's two-and-a-half hours of study before dinner, he reviews his notes for the preceding two weeks of lectures and outlines the five textbook chapters that are to be tested on the exam. To test his mastery of the material, Alan attempts to answer a list of study questions that the instructor has provided. Once he has written an answer for each of the 35 questions, he begins to check the accuracy of his responses, only to be interrupted by his father's calling him to dinner.

Clearly, Alan's before-dinner activities, both physical and mental, were based to a considerable degree on information represented in his long-term memory store. In this chapter, we shall examine the ways in which learning and memory psychologists attempt to characterize and classify long-term memory representations.

DISTINCTION BETWEEN PROCEDURAL AND DECLARATIVE KNOWLEDGE

The issue of how information is represented in long-term memory is one of major importance to theorists of human memory. A number of these theorists have proposed descriptions of long-term memory that focus on the types of information represented in long-term store and how that information is organized. In this chapter, some of the most influential characterizations of long-term store will be considered. Most of these formulations represent the cognitive approach to memory in that they include assumptions about the organization of mental events that go beyond the notion of simple associative linkages between items in memory. However, in many of these treatments the influence of associationism will also be evident. Thus, as in preceding chapters, further evidence of the almost universal appeal of certain associative notions will be encountered, underscoring again how, despite its limitations as a comprehensive explanation of mental life, associationism remains a major influence in descriptions of memory.

ACT Theory's Proposed Distinction

In 1976, John Anderson proposed a computer simulation model of cognitive processes that he dubbed ACT (for Adaptive Control of Thought). Since then, he has continued to revise and refine the framework (e.g., see Anderson 1983, 1987, 1989, 1990). Anderson sees ACT as a successor to an earlier computer simulation model, HAM (for human associative memory), that he developed in conjunction with Gordon Bower (Anderson & Bower, 1973). The model describes the cognitive system in terms of two components: **declarative knowledge,** which refers to knowing facts, and **procedural knowledge,** which involves knowing how. Declarative knowledge, it is assumed, is organized into an associative network, and procedural knowledge is represented as a production system that operates on that factual knowledge in the performance of various tasks.

For example, in unlocking his bicycle and riding it home, Alan was, in Anderson's terms, relying on both declarative knowledge and the execution of productions. Alan was relying on declarative knowledge in that the knowledge of facts, such as *I parked my bike in the rack outside the science building,* is presumably involved in performing the skill. Alan was relying on productions in that unlocking and riding a bicycle obviously involves "knowing how" in the sense of executing a series of step-by-step procedures when certain conditions are met. For example, the production for unlocking the bicycle might involve the step of turning the key to the right once the key has been fully inserted into the bike lock. Thus Anderson's model assumes the existence in long-term memory of a body of factual, or declarative, knowledge that determines when and under what conditions procedural knowledge in the form of ordered productions is exhibited.

What is the basic distinction ACT makes between declarative and procedural knowledge?

Declarative Knowledge as a Network of Associated Propositions

In arguing that declarative knowledge is organized in an associative network, Anderson makes the further assumption that declarative knowledge is represented in the form of propositions. In the sense used by Anderson and other cognitive psychologists, a **proposition** is defined as a unit of language that expresses a relationship between two or more concepts. Alternatively, a proposition can be defined as the smallest unit of language about which it makes sense to judge true or false.

Consider the sentence *The happy boy who lives next door hit the bicycle.* This sentence can be described as consisting of three propositions: (1) the boy is happy, (2) the boy lives next door, and (3) the boy hit the bicycle. Each of these units specifies a relationship between at least two concepts, and it is possible to judge the truth of the unit, whereas it is not possible to judge the truth of a unit such as "the boy." If one assumes that this sentence is represented in memory in the form of its constituent propositions, then one can further assume that these constituent propositions are linked into a network by means of labeled associations (see Figure 7–1).

In this figure, the associative links are labeled in terms of the relationship that exists between the two linked concepts. This assumption has been justified by Anderson and Bower (1973) and others (e.g., Collins & Quillian, 1969; Collins & Loftus, 1975) on the basis of retrieval efficiency. It is argued that the labeling of associations within the memory network would speed retrieval by limiting the number of associative links leading from a concept that would have to be searched. For example, if a subject studies the to-be-remembered sentence *The boy hit the ball,* and then is prompted with the sentence frame *The* ______ ______ *the ball,* the memory search can be limited to those associative pathways from *ball* labeled with an "object" relationship.

However, Anderson (1975) failed to find empirical support for this assumption. He found that the speed of verifying as true or false a sentence containing a particular concept, such as *Nixon,* was affected by the total number of sentences studied in which *Nixon* appeared, regardless of the logical role of *Nixon* in the various sentences. Thus Anderson found that if subjects, for example, studied 10 sentences in which *Nixon* appeared as subject and only 1 sentence in which *Nixon* appeared as object and were then asked to decide if the

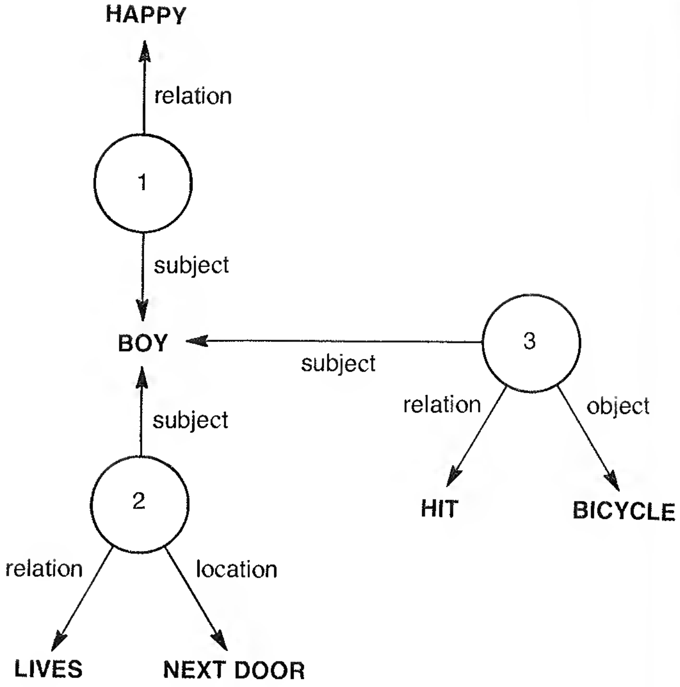

FIGURE 7–1 The sentence *The happy boy who lives next door hit the bicycle* represented as three constituent propositions linked by labeled associations.

sentence *The lawyer kicked Nixon* had been studied, they were just as slow as were subjects who had studied 10 sentences in which *Nixon* appeared as object and only one sentence in which *Nixon* appeared as subject. Thus ACT assumes that a memory search will evaluate all propositions containing a target concept regardless of the relationship the concept has to the rest of the proposition.

However, ACT still assumes that associative links are labeled and that these labels are used in evaluating possibly relevant propositions activated by the search process. That is, the associative links between concepts must be labeled if the propositional representation is to express precisely the meaning of the information being represented. If the representation of *The boy hit the bicycle,* as shown in Figure 7–1, did not indicate the relationship that existed between *hit* and *boy* and between *hit* and *bicycle,* it would not be possible upon retrieving the representation from memory to decide whether the boy hit the bicycle or the bicycle hit the boy, unless additional information regarding word order in the original sentence was represented in memory. However, it is obviously highly desirable to have an abstract representation of information that is independent of order of information. Otherwise, the basic underlying similarity of *The boy hit the bicycle* and *The bicycle was hit by the boy* would not be adequately reflected in the system.

In what form does ACT assume that declarative knowledge is represented in long-term memory?

Procedural Knowledge as a System of Productions

Anderson (1976, 1983, 1987, 1990) defines a **production** as a rule consisting of a condition and an action. In turn, the condition consists of a goal and a set of tests for determining if the production is appropriate to the goal. If the application tests are satisfied, the action is performed. Table 7–1 contains some example productions. In the shifting gears production, the actions of depressing the clutch, moving the stick to the upper right, and releasing the clutch are only executed if the goal is to shift from first to second gear and if the car is currently in first gear, going more than 10 miles an hour, and has a clutch and a stick shift.

TABLE 7–1 Example Productions from Anderson's ACT System

Production for Shifting Gears

Production:	Changing from first to second gear in one kind of car.
IF	the car is in first gear and the car is going faster than 10 mph and there is a clutch and there is a stick shift,
THEN	depress the clutch and move the stick to the upper right and release the clutch.

Production for Making a Noun Plural

Production:	One way to make a noun plural.
IF	the goal is to generate a plural noun and the noun ends in a hard consonant,
THEN	generate the noun with an "s" on the end.

Production for Parsing a Sentence

Name of Production		*Form of Production*
NP	IF	the string is of the form *A noun*
	THEN	the meaning is an instance of *noun*
RELATIVE	IF	the string is of the form *person who verb object*
	THEN	the meaning is that *person* has the relation *verb* to *object*
MAIN	IF	the string is of the form *person verb object*
	THEN	the meaning is that *person* has the relation *verb* to *object*

Production for Inferencing

IF	person 1 is the father of person 2 and person 2 is the father of person 3
THEN	person 1 is the grandfather of person 3.

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It is important to understand that in describing procedural knowledge as a collection of production systems, Anderson is not limiting his conceptualization to procedures involving physically observable actions, such as shifting gears or riding a bicycle. He includes within his conceptualization of procedural knowledge cognitive activities such as making a noun plural and parsing a sentence (i.e., analyzing the sentence into its constituent parts so as to make interpretation of its meaning possible), and drawing inferences. Productions that might be involved in these activities are also shown in Table 7–1.

The production for making a noun plural is self-explanatory. In the production for parsing a sentence, three productions are applied. The first identifies a noun phrase and assigns a meaning to it. The second identifies a relative clause embedded in the original noun phrase and assigns a meaning to the whole unit. The third identifies a complete sentence pattern consisting of the already interpreted noun phrase plus verb and object and assigns a meaning to the complete sentence. This sentence parsing example is instructive in illustrating how ACT theory stresses the organization of productions into subroutines that continually interact with each other in the execution of some procedure.

The third set of productions for inferencing would be appropriate if an individual were holding in short-term or working memory information such as *John is the father of Bill* and *Bill is the father of Steve.* The execution of the production would result in the action of recording in working memory that *John is the grandfather of Steve.* This example production shows how productions are driven by, and in turn influence the contents of, working memory.

☑ *What, according to ACT, are productions, and how are they involved in the representation of procedural knowledge?*

Distinguishing Features of Procedural and Declarative Knowledge

In justifying the distinction between procedural and declarative knowledge, Anderson argues that declarative knowledge is possessed on an all-or-none basis, whereas procedural knowledge can be possessed partially or in degrees. For example, Alan either knows or doesn't know where in a woman's body the ovum if fertilized, but Alan can possess the ability to shoot a hook shot to varying degrees. Furthermore, Anderson contends that declarative knowledge can be described verbally or expressed symbolically through language, whereas procedural knowledge often cannot be. Procedural knowledge can often only be demonstrated through the performance of specific behaviors. Alan, for example, might have great difficulty describing verbally how he executes a lay-up, whereas he might be able to demonstrate the move easily. Finally, Anderson suggests that declarative knowledge is often acquired rapidly through a single experience, whereas procedural knowledge is often acquired only gradually through repeated experience or practice in performing the skill. Alan's knowledge of where an ovum is fertilized may be acquired from a single reading of a passage in the textbook, but his knowledge of how to execute a hook shot is likely to be acquired only through repeated practice of the skill.

☑ *In what three ways do procedural and declarative knowledge differ?*

Interactions of Procedural and Declarative Knowledge

Although procedural and declarative knowledge are assumed to be distinct, ACT also assumes that there is constant interaction of procedural and declarative knowledge. The nature of this interaction is represented in Figure 7–2. The execution of productions in utilizing procedural knowledge is determined by information held in working memory, and

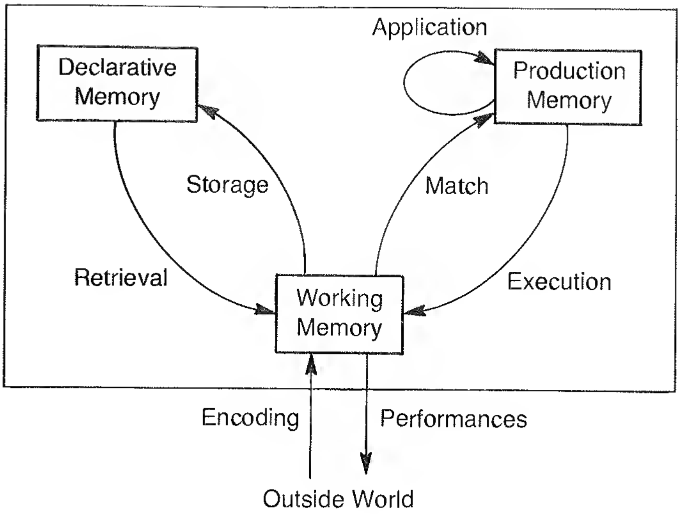

FIGURE 7–2 An illustration of the interaction of declarative and procedural knowledge in the ACT framework.

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the information in working memory is provided by the long-term declarative knowledge propositional network in conjunction with sensory inputs from the outside world. That is, production systems are driven by data provided to working memory by the declarative knowledge propositional network. Such data include information about the current stimuli being encountered, past memories, current goals, and so on.

For example, Alan's execution of productions involved in riding his bicycle might be influenced by traffic patterns on the sidewalk adjacent to the bike rack and on the streets on his route, his recollection of a major construction project on one of the streets he normally travels, and his desire to be home in time to study before dinner.

Furthermore, productions are only executed if the declarative knowledge propositional network specifies through working memory that certain conditions have been met. Alan will only exert pressure on the right pedal of his bicycle through his right leg once the bicycle lock has been removed and the bicycle is oriented properly for riding to begin.

Finally, once executed, productions result in changes in working memory and in the declarative knowledge propositional network. Once an action such as removing the lock has been performed, this knowledge must be represented in Alan's system in order for relevant productions involved in riding the bike to proceed. Similarly, once Alan has arrived at a meaningful interpretation for a passage in his biology textbook through the application of relevant productions, this interpretation must be represented in Alan's declarative memory system in order for productions involved in integrating the textbook information with lecture material to proceed.

How specifically does declarative knowledge affect the execution of productions, and how does the execution of productions affect declarative knowledge?

Evidence Consistent with the Distinction

Performance of Amnesics. One body of evidence that has been cited as consistent with the distinction between procedural and declarative knowledge comes from the study of persons suffering from **anterograde amnesia.** This memory deficit is associated with brain trauma of various sorts and is characterized by difficulty in forming new long-term memories for events occurring *after* the brain trauma. In his description of the memory deficits of these amnesics, Baddeley (1983) cites a number of findings consistent with the assumption that procedural knowledge may be relatively intact in such individuals but that they suffer from a profound difficulty in effectively encoding new declarative knowledge.

For example, Baddeley notes that amnesics are relatively unimpaired in learning motor skills such as those involved in performing a pursuit rotor task, tracing a path through a maze, and performing a typing task. They are also unimpaired in perceptual learning tasks. For instance, they are able to detect an anomaly in a drawing faster and faster with repeated presentation of the drawing (Warrington & Weiskrantz, 1973), and they are able to assemble a jigsaw puzzle faster and faster with repeated presentations of the puzzle. However, anterograde amnesics' profound deficits in acquiring new declarative knowledge is illustrated by the fact that in all of the cases of procedural learning just noted, the amnesics reported no awareness of earlier trials as the trials on the task continued. That is, the amnesics apparently had no conscious awareness of the prior learning episodes.

Additional evidence of amnesics' deficits in acquiring new declarative knowledge will be described in Chapter 11. At present, it is sufficient to note that this pattern of deficits in anterograde amnesics is being widely interpreted as supporting the distinction between procedural and declarative knowledge.

Independent Acquisition of Procedural and Declarative Knowledge. Another line of research that has been advanced in support of the distinction between procedural and declarative knowledge involves attempts to demonstrate that procedural learning can develop in normal subjects in the absence of conscious awareness (i.e., in the absence of declarative knowledge) that the learning is occurring. Willingham, Nissen, and Bullemer (1989) had subjects perform a reaction time task that involved pressing one of four keys, arranged horizontally beneath four different locations on a video monitor. The subject's task on each trial was to press as quickly as possible the key beneath the location in which an asterisk appeared. Unbeknownst to the subjects, the location of the asterisk was varied according to a predetermined pattern that recurred every 10 trials. Thus, over the entire set of 40 trials, subjects experienced the same 10-trial sequence of asterisk locations four times in succession.

Subjects were questioned after the reaction time procedure concerning their awareness of any repeating pattern or sequence, and a number of the subjects reported no awareness whatsoever of the repeating pattern. However, when the reaction time data from these subjects who reported no conscious awareness of the repeating sequence were analyzed, Willingham and colleagues found that these subjects nevertheless showed a significant decrease in reaction time (i.e., they came to respond faster) across the four blocks of 10 trials (Figure 7–3). This decrease in reaction time cannot be attributed to subjects' simply learning about the general demands of the task because Nissen and Bullemer (1987) showed that subjects exposed to truly random asterisk placement showed a minimal reduction in reaction time across blocks of trials.

Thus some of the subjects with normal memory studied by Willingham and colleagues showed specific procedural learning in the absence of explicit declarative knowledge, just as persons with amnesia do. These results support the validity of ACT theory's distinction between procedural and declarative memory. However, the researchers note that the results are at odds with Anderson's (1987) claim that procedural knowledge is necessarily derived

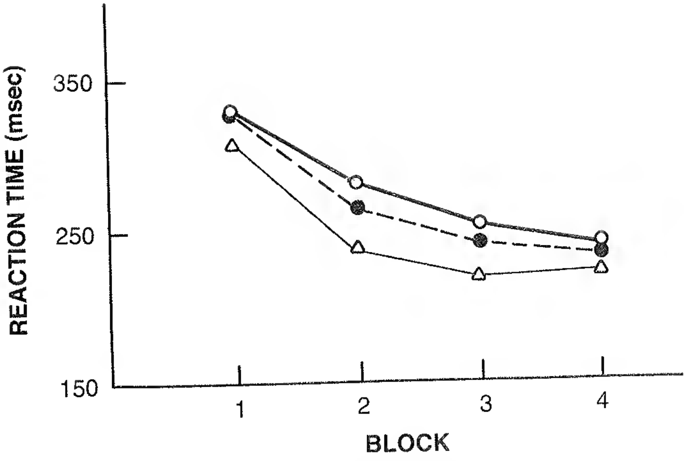

FIGURE 7–3 Reaction times of subjects to visual targets presented in different locations across blocks of trials as a function of degree of declarative knowledge possessed about the repeating sequence of target placements. (Open circles = no declarative knowledge; filled circles = some declarative knowledge; open triangles = full declarative knowledge.)

Source: Willingham, D. B., Nissen, M. J., & Bullemer, P. (1989). On the development of procedural knowledge. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 1051. Copyright 1989 by the American Psychological Association. Reprinted by permission.

from preexisting declarative memory representations of the same information. It would appear that in some situations the development of procedural knowledge can precede the development of corresponding declarative knowledge.

What evidence from the study of anterograde amnesics and the development of procedural learning in normal subjects supports the distinction between declarative and procedural knowledge?

Explicit versus Implicit Memory

The sort of evidence summarized above as supporting the distinction between declarative and procedural knowledge can also be interpreted as supporting a distinction between explicit and implicit memory (e.g., see Graf & Schacter, 1985; Johnson & Hasher, 1987; Richardson-Klavehn & Bjork, 1988; Schacter, 1987). **Explicit memory** refers to memory displayed in response to a direct test of memory that taps an individual's awareness that he or she is remembering a specific prior event. **Implicit memory,** on the other hand, refers to memory displayed in response to an indirect test of memory that does *not* tap an individual's awareness of a specific prior event but that does assess whether his or her current behavior is being influenced by some prior event.

In the case of the amnesics' performance described earlier, the measures of motor skill learning and perceptual learning were indirect tests of memory in that subjects were being tested to determine whether prior performance of the tasks influenced later performance of the tasks, regardless of the subjects' awareness of having previously performed the tasks. On the other hand, asking the amnesic subjects if they remembered having performed the task previously was a direct test of memory. Thus the performance of the amnesic subjects can be interpreted in terms of their having impaired explicit memory but intact implicit memory.

Similarly, the results from the Willingham, Nissen, and Bullemer (1989) study described in the immediately preceding section can be interpreted in terms of the subjects developing implicit memory for the repeating asterisk pattern in the absence of explicit memory for the pattern. Although the distinction between explicit and implicit memory may ultimately be found to be subtly different from the distinction between declarative and procedural memory, we shall follow the lead of Anderson (1990). We shall equate explicit memory with declarative memory, because explicit memories are those of which a person is conscious and can declare, and we shall equate implicit memory with procedural memory, because the performance underlying demonstrations of implicit memory is based on performing various kinds of procedures.

✎ *How can the distinction between explicit and implicit memory be explained in terms of the distinction between declarative and procedural knowledge?*

The Cognitive-Associative Traditions

ACT nicely illustrates the continuing the influences of the cognitive and associative traditions on the study of learning and memory processes. Principles of associationism are the basis of ACT's representation of the declarative knowledge system. However, in augmenting this characterization of declarative memory as an associative network with a description of procedural knowledge based on the concept of productions, Anderson has introduced notions that go well beyond simple associationist principles of mental life. Perhaps Anderson's demonstration that associationist notions can be integrated so effectively with more complex cognitive functions will be one of the most enduring aspects of his work.

✎ *Is ACT primarily cognitive or associationist in its focus?*

Schemas as a Component of Procedural and Declarative Knowledge

Schema Defined

Another notion concerning the representation of information in long-term memory that can be used to supplement the distinction between procedural and declarative knowledge is that of schemas. Earlier in this century, Englishman Sir Frederic Bartlett (1932) argued that information in memory is highly organized into structures called **schemas.** These knowledge structures concerning objects, events, situations, and the like in turn influence how new episodes are represented in memory by arousing expectations that influence how the new information is interpreted and incorporated into the existing schemas.

These schemas, or existing knowledge structures, thus influence what Bartlett called the "effort after meaning." That is, he argued, human learners do not passively store away the information that is presented to them. Instead, they attempt to arrive at a meaningful interpretation of the information, and this interpretation is strongly influenced by prior knowledge that is activated at the time of study. Bartlett suggested that the more successful the individual is in his or her effort after meaning, the more successful the learning will be.

Returning again to the example of Alan, Bartlett would argue that in studying for his biology exam, Alan will activate schemas relevant to the topic being studied. In studying the material on human reproduction, Alan might use previously established general schemas regarding fertilization of the ovum as a basis for interpreting and integrating in memory new information concerning the specific physiological processes that are involved in the uniting of ovum and sperm cell. Alan's schema might include the information that each ovum and sperm cell contains 23 chromosomes, and such knowledge might lead him to expect to find in the textbook material information about how the chromosomes are involved in the physiological processes that constitute fertilization.

What is a schema?

Schemas and Comprehension of Text

Bartlett's notion of schemas was popularized in the 1970s in part by the work of Bransford and colleagues. In a landmark study, Bransford and Johnson (1972) presented subjects with the following passage and asked them to study it for a later memory test. Try this task yourself. Read the passage through once at your normal reading speed. Then put your textbook aside and write your recall of the passage. Try to make your recall as similar to the original passage as possible.

> *The procedure is actually quite simple. First you arrange items into different groups. Of course one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities that is the next step; otherwise, you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then, one never can tell. After the procedure is completed one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more and the whole cycle will then have to be repeated. However, that is part of life. (Bransford & Johnson, 1972, p. 322)*

Now, if you found this passage difficult to comprehend and recall, you had the same experience as those subjects in Bransford and Johnson's experiment who heard the passage without first being given a title for the passage. However, suppose that you were told in advance of reading the passage that the topic of the passage is "washing clothes." Read the passage again now. You probably find it much more understandable.

Bransford and Johnson found that subjects who received the title before hearing the passage rated it as significantly more comprehensible and recalled significantly more of it. Subjects given the topic information *after* hearing the passage rated it as no more comprehensible and recalled no more of it than did those subjects given no topic information at all. Thus these results suggest that the activation of relevant schemas contributes importantly to the comprehension and retention of to-be-remembered information.

This line of research has been further developed by researchers such as Voss and associates, who have focused on the relationship between the reader's prior knowledge about a particular topic, such as baseball, and the ability to comprehend and recall the information. In one study, for example, Chiesi, Spilich, and Voss (1979) manipulated at input the number of context sentences preceding the baseball-related sentence that was the target of the investigation. When subjects were asked to recall target sentences that had been presented alone, subjects with low preexisting knowledge about baseball did just as well as subjects with high preexisting knowledge about baseball. However, recall of target sentences by low-knowledge subjects declined as the number of context sentences increased, whereas recall of target sentences by high-knowledge subjects increased as the number of context sentences increased.

Voss (1984) interprets these findings as showing that low-knowledge subjects were not adept at integrating the sentence sequence and thus suffered interference as a result of treating the sentences as separate pieces of information. Similarly, Wilhite (1988, 1989) has examined the effectiveness of headings in text in promoting retention of the information as a function of readers' prior knowledge about the topic. He found that only high-knowledge subjects benefited from the inclusion of headings. Wilhite suggests that readers lacking relevant prior knowledge may not be able to use headings as an integrative device with regard to the organization and retention of passage information.

How does the research of Bransford and Johnson and the research of Voss and associates support the contention that schemas are important in comprehension and memory of text?

Structure of Schemas

Other researchers have attempted to characterize the structure of schemas in long-term memory. Rumelhart and Ortony (1977) have presented the examples of schemas for *break* and *face* shown in Figure 7–4. As these diagrams show, Rumelhart and Ortony assume that schemas are composed of a network of interrelated concepts or subschemas. Thus, in the

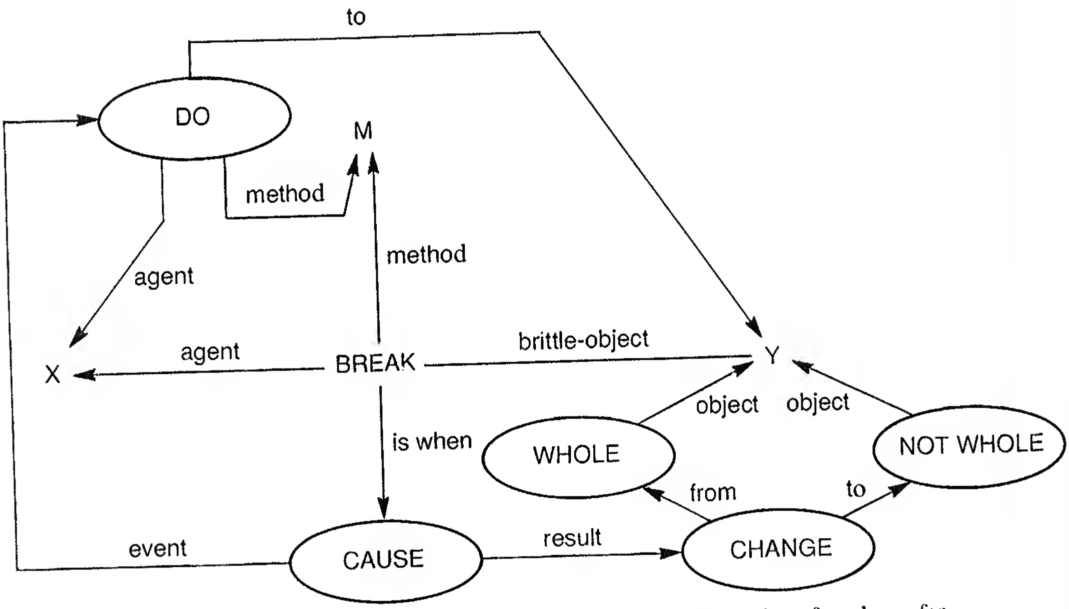

FIGURE 7–4 Representation of a schema for *break* and a partial representation of a schema for *face*.

Source: D. E. Rumelhart & A. Ortony (1977). The representation of knowledge in memory. In R. C. Anderson, R. J. Spiro, & W. E. Montague (Eds.), *Schooling and the acquisition of knowledge*. Hillsdale, NJ: Erlbaum. Reprinted with permission.

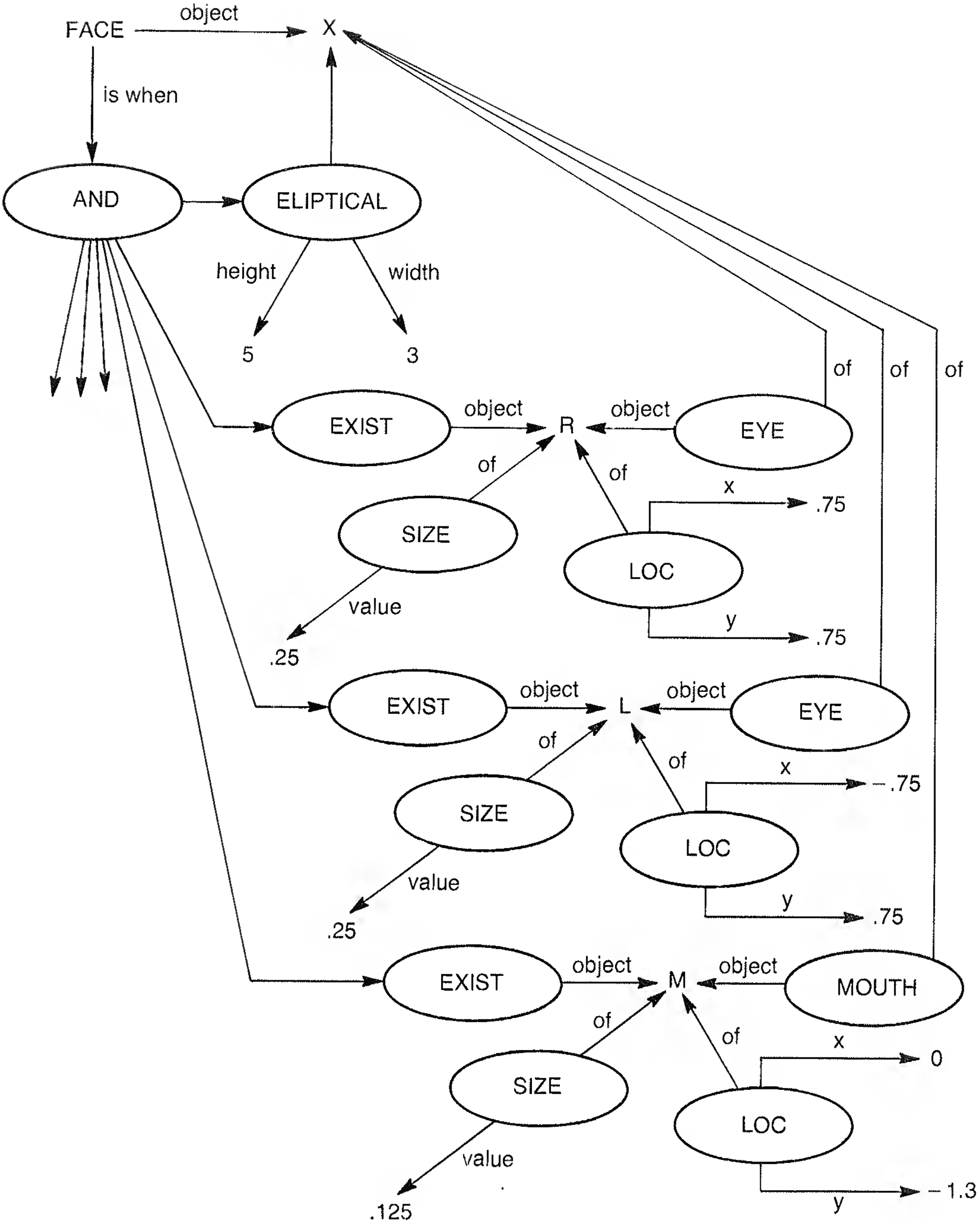

FIGURE 7–4 Continued

case of *break,* the schema includes the subschemas of *do, cause, whole, change,* and *not whole.* The schema also includes the variables *x, y,* and *M.* (A **variable** is a slot in the schema that can take on different values as a function of the situation or context in which the schema is activated.) There are, however, constraints built into the schema that limit the range of values a variable can assume. As Figure 7–4 shows, the variable *y,* as the object of the action, must have the property of being brittle, and the variable *x,* as the agent of the action, must be capable of initiating the action.

In turn, the values of *x* and *y* will influence the value assigned to *M,* the method of breaking employed. Consider the following sentences:

> David broke the glass.
> David broke the chain.

According to Rumelhart and Ortony's conceptualization, both of these sentences would result in *x* being bound to *David,* whereas *y* would be bound to *glass* in the case of the first sentence and to *chain* in the case of the second sentence. These two different bindings of *y,* in turn, suggest different interpretations of *M,* the method. In the first case, the method may be interpreted, depending on the context, as involving the act of dropping the glass; whereas, in the second case, the method my be interpreted as involving the act of pulling or yanking on the chain.

This notion that there are slots or variables in the schema can help explain how humans interpret verbal material by drawing inferences that go beyond the information actually provided. In many cases, the material encountered will activate schemas and yet fail to fill all of the slots or variables. In such situations, some of the slots may be filled with the most typical or expected value for the variable. That is, the system makes use of what is known as **default knowledge.** Consider the following passage about a construction site from a study by Johnson, Bransford, and Solomon (1973):

> *The construction worker was trying to secure the door frame. He was pounding the nail when the foreman came out to watch him and help him do the work. (p. 203)*

When given a recognition test on the passage, many subjects incorrectly indicated that the following sentence had been presented in the passage:

> *The construction worker was using a hammer to secure the door frame when the foreman came out to watch him and help him do the work.*

Such a finding can be explained by assuming that, in the absence of explicitly supplied information about the instrument being used, that slot in the *pound* schema was filled with the default value *hammer.*

What are slots or variables in a schema, and how are they related to default knowledge?

Relationship of Schemas to Declarative and Procedural Knowledge

The example schemas for *break* and *face* discussed by Rumelhart and Ortony (1977) are obviously in some sense much more elemental or specific than schemas for washing clothes, sexual reproduction, or baseball, cited earlier in the discussion of other research focusing on the role of schemas in comprehension and memory. However, Rumelhart and Ortony are in no sense suggesting that schemas are limited to the representation of relatively simple concepts. Rather, they argue that one think of schemas in memory as being embedded within each other. Just as the representation of the *face* schema shown in Figure 7–4 shows the schemas of *eye* and *mouth* embedded within it, one could construct a representation of a *washing clothes* schema that would include within it subschemas for *sorting clothes, loading the washing machine, starting the washing machine,* and so on. Thus one can talk about schemas of varying levels of specificity.

The issue of schemas will be considered again later in Chapter 9 in conjunction with the issue of retrieval through reconstruction. At present, it is sufficient to note that the assumption of the existence of schemas is compatible with the assumption of discrete, yet interrelated, representations for declarative and procedural knowledge. In fact, Rumelhart (1980) has explicitly likened the operation of schemas to the performance of procedures, arguing that "schemata are active computational devices capable of evaluating the quality of their own fit to the available data" (p. 39). In the example above concerning the construction site passage, arriving at a meaningful interpretation of the passage presumably involved a procedure for filling the instrument slot in the *pound* schema that included a production for activating the default value *hammer.* Thus, to the extent that schemas are a psychological reality, their activation and use might also involve procedural knowledge in the form of productions.

How can schemas be incorporated into the distinction between declarative and procedural knowledge?

DISTINCTION BETWEEN SEMANTIC AND EPISODIC KNOWLEDGE

If one accepts the distinction between procedural and declarative knowledge as persuasive, there are additional assumptions about the representation of information in long-term memory that can be incorporated into the procedural-declarative distinction. One of these is Tulving's (1972, 1983, 1984) suggestion that propositional declarative knowledge in long-term memory can be divided into distinct episodic and semantic systems. One means of representing this classification of long-term memory systems is shown in Figure 7–5.

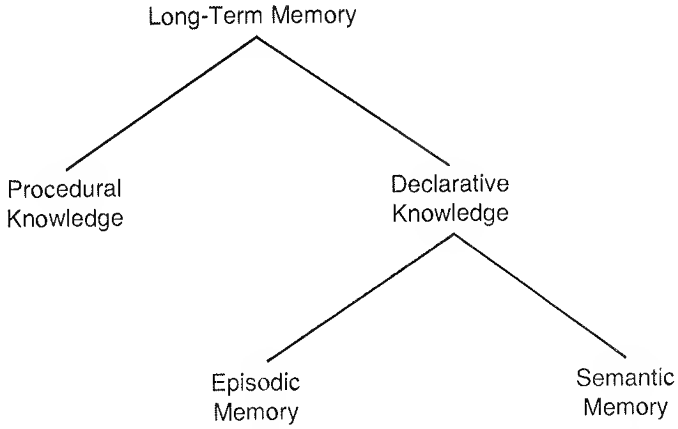

FIGURE 7–5 One possible organization of long-term memory systems.

Tulving's Rationale for the Distinction

Tulving (1972) suggests that it is useful to conceptualize **semantic memory** as "memory necessary for the use of language" (p. 386). As such, semantic memory includes memory for the meaning of words and concepts, grammatical rules governing the order of words in sentences, and so on. Thus semantic memory can be thought of as a storehouse of general world knowledge in which the information is independent of when and how it was learned. On the other hand, Tulving (1983) argues, **episodic memory** should be thought of as memory for "temporally dated episodes or events and temporal-spatial relations among them" (p. 223). That is, episodic memory is autobiographical memory that includes temporal information about past events and episodes.

Episodic memory is memory for personally experienced unique episodes. For example, an item in a to-be-remembered list could be coded in episodic memory in terms of the fact that it was presented visually and not aurally, that it occurred in List 1 rather than List 2, that it was near the beginning of the list, that recall was going to be required, and so on. Tulving argues that most memory experiments tap episodic rather than semantic memory. That is, the subject is being asked to remember that the presented information was part of a specific temporal-contextual event. In Tulving's formulation, the studying of a word in a to-be-remembered list results in the creation of a unique episodic representation of the item. Information about the word from the semantic memory store may be included in the episodic representation, but the episodic representation of the word is separate and distinct from the semantic representation. This interaction of episodic and semantic systems is illustrated in Figure 7–6.

In the case of Alan, presented at the beginning of the chapter, the operation of episodic and semantic memory systems would be initiated by different types of memory tasks. If, upon arriving at home, Alan was asked by his brother whether he picked up a videotape at the local video store, Alan's response would be based on episodic information. Likewise, if Alan received a telephone call from a classmate who asked him if he had yet studied the chapter in his biology textbook on endocrinology, in responding he would tap episodic memory for his recent study activities. On the other hand, if Alan attempted to explain to his younger brother how the type of clothes worn when cycling is related to wind resistance and speed, he would rely primarily on his semantic memory. Similarly, if Alan proceeded to explain to his classmate the distinction in biology between excitatory and inhibitory neurotransmitters, Alan would be tapping his semantic memory store.

Tulving argues that episodic information is more vulnerable to interference than semantic information because episodic memory is organized temporally, whereas semantic memory is organized conceptually. This difference in organization also has implications for retrieval of the information. According to Tulving, retrieval from episodic memory often requires conscious, deliberate effort, whereas retrieval from semantic memory tends to be automatic.

How does Tulving distinguish between semantic and episodic knowledge?

Evidence Supporting the Distinction

Dissociation Effects

In summarizing evidence consistent with this distinction, Tulving (1983, 1984) has focused on **dissociation effects** or evidence that variables affect performance on semantic and

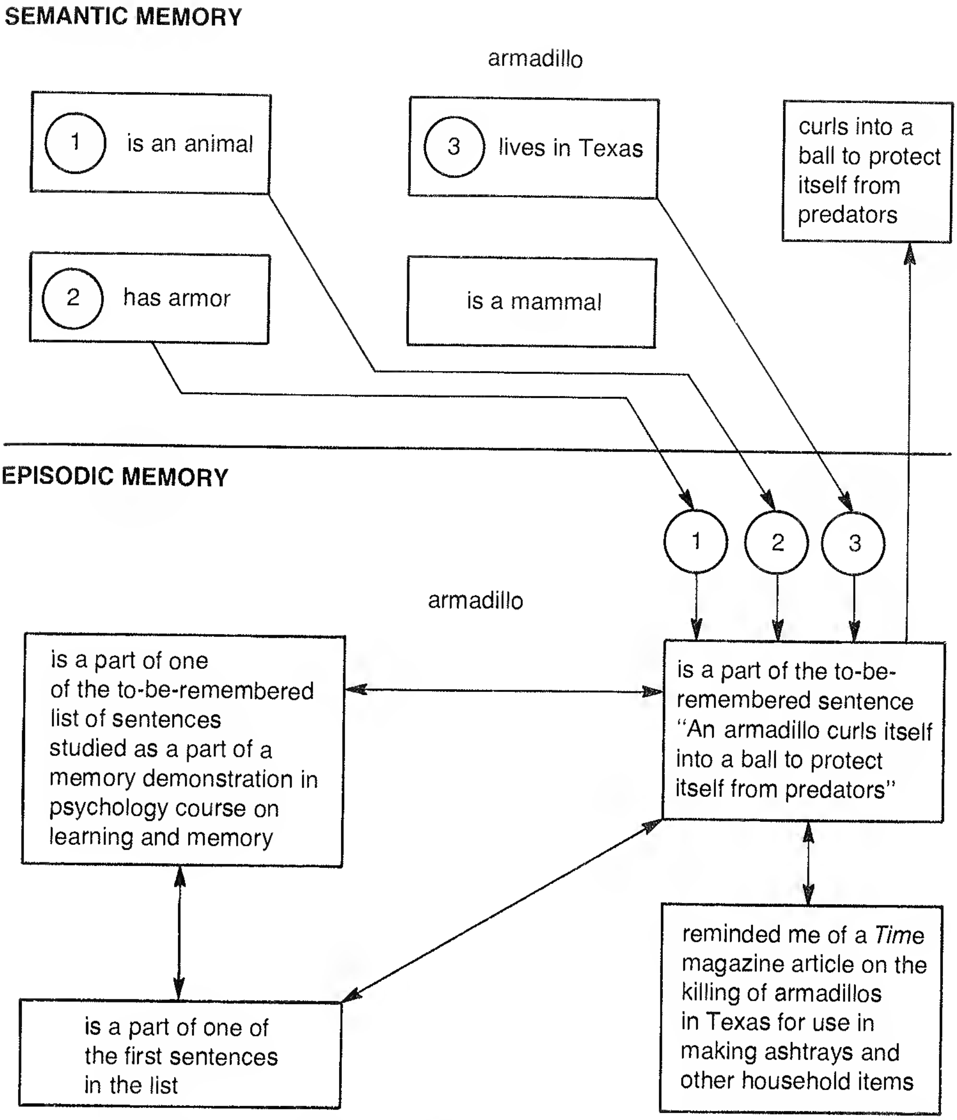
SEMANTIC MEMORY
armadillo
1 is an animal
3 lives in Texas
curls into a ball to protect itself from predators
2 has armor
is a mammal
EPISODIC MEMORY
1
2
3
armadillo
is a part of one of the to-be-remembered list of sentences studied as a part of a memory demonstration in psychology course on learning and memory
is a part of the to-be-remembered sentence "An armadillo curls itself into a ball to protect itself from predators"
is a part of one of the first sentences in the list
reminded me of a Time magazine article on the killing of armadillos in Texas for use in making ashtrays and other household items

FIGURE 7–6 An illustration of the interaction of semantic and episodic memory in remembering the sentence *An armadillo curls itself into a ball to protect itself from predators.* In this illustration, semantic elements 1, 2, and 3 are assumed to be activated and included in the episodic encoding of the sentence. This illustration also assumes that the studying of the sentence results in the addition of new general information to the semantic representation of *armadillo.*

episodic tasks differently. In one two-phase experiment, Jacoby and Dallas (1981) had subjects perform a levels of processing task in the first phase of the study. For each word presented, subjects made a judgment about either its appearance (*Is the word in capital letters*?), its sound (*Does the word rhyme with DIME*?), or its meaning (*Would the word fit in the sentence "He folded his hands across his ______"?*).

In the second phase of the experiment, subjects performed either a semantic task or an episodic task on the words. The semantic task required subjects to respond as quickly as possible with the name of each word presented very briefly in a tachistoscope (a device for briefly presenting visual stimuli). Some of the words presented in this naming task were the same as the words presented in the first phase of the study. The episodic task consisted of a standard recognition test on the words presented in the first phase of the study. That is, the words presented in the first phase of the study were presented in conjunction with a number of words that had not been presented in the first phase of the study, and the subjects had to judge whether each word on the test had been presented in the first phase of the experiment.

As shown in Table 7–2, Jacoby and Dallas found that the type of processing to which the words were subjected in the first phase of the study had a large effect on performance on the episodic task in phase two but had no effect on performance on the semantic task in phase two. That is, subjects in phase two who performed the recognition test were significantly better at correctly recognizing phase one words about which they had made meaning judgments than they were at correctly recognizing phase one words about which they had made either appearance or sound judgments. However, subjects in phase two who performed the naming task did not differ in the accuracy with which they correctly named phase one words about which they had made either appearance, sound, or meaning judgments. Thus the type of judgments made about words in the first phase of the study affected performance on the following episodic task but not on the following semantic task, supporting the contention that the episodic and semantic systems are distinct.

A study by Kihlstrom (1980) involving subjects with differing degrees of hypnotizability has also been cited by Tulving as supporting the same conclusion. In this study, subjects of either very high, high, or medium to low hypnotizability learned words under hypnosis and were then given posthypnotic suggestions to forget them. In the posthypnotic period, some of the subjects were asked to perform the semantic task of free association in which one responds to presented words with the first word that comes to mind. Some of the words presented as prompts were strong associates of words studied in the first part of the study. Other subjects were asked to perform the episodic task of free recalling the words studied in phase one of the experiment.

As shown in Table 7–3, Kihlstrom found that hypnotizability of the subjects was strongly associated with performance on the episodic task but not on the semantic task. That is, the more hypnotizable the subject, the more likely the subject was to comply with the suggestion to forget and thus the lower the subject's free recall score was. However, the

TABLE 7–2 Response Probabilities from a Study by Jacoby and Dallas (1981) Showing Evidence of Dissociation Effects for Semantic and Episodic Tasks

	First-Phase Encoding Condition		
Task	*Appearance*	*Sound*	*Meaning*
Semantic identification	.80	.81	.82
Episodic recognition	.50	.63	.86

Source: Tulving, E. (1983). *Elements of episodic memory*. Oxford, England: Oxford University Press. By permission of Oxford University Press.

TABLE 7–3 Response Probabilities from a Study by Kihlstrom (1980) Showing Evidence of Dissociation Effects for Semantic and Episodic Tasks

	Hypnotizability of Subjects		
Task	*Very High*	*High*	*Medium/Low*
Semantic free association	.61	.50	.53
Episodic free recall	.01	.47	.86

Source: Tulving, E. (1983). *Elements of episodic memory.* Oxford, England: Oxford University Press. By permission of Oxford University Press.

hypnotizability of the subject was not related to the tendency of the subject to generate a word studied in phase one in response to a strong associate on the free association task in phase two.

What sorts of dissociation effects has Tulving used in arguing for the semantic-episodic distinction?

Performance of Amnesics

Certain phenomena from the study of amnesia are also interpretable in the context of the episodic-semantic distinction (Tulving, 1983, 1984; Tulving, Schacter, McLachlan, & Moscovitch, 1988; Lewis, 1986). In a study by Warrington and Weiskrantz (1974), the performance of amnesic and control subjects was compared on a standard episodic recognition test and a semantic word-fragment completion task. In the word-fragment completion task, the subject is given a stem such as ST __ __ __ and is asked to supply the missing letters so as to make a word. The researchers found that control subjects performed significantly better than amnesics on the episodic recognition task, but the amnesics and controls did not differ significantly on the semantic word-fragment completion task. Such evidence suggests that the primary deficit of some amnesics may be limited to the episodic memory system.

How can the performance of amnesics be explained in terms of the episodic-semantic memory distinction?

Criticisms of the Distinction

In 1984, Tulving published in the journal *Behavioral and Brain Sciences* a summary of his 1983 book, *Elements of Episodic Memory,* in which he had described in elaborated fashion his conceptualization of the episodic-semantic distinction. As is the custom with that journal, commentary on the summary was invited from other theorists and researchers. In the commentaries, one of the most common objections was that neither reasoned argument and conjecture nor available empirical evidence support the assumption that propositional declarative knowledge is organized in long-term memory into two separate and discrete systems.

Objections to the Conceptual Basis for the Distinction

A number of memory theorists (e.g., Hintzman, 1984; Kihlstrom, 1984; Klatzky, 1984; Lachman & Naus, 1984; McKoon, Ratcliff, & Dell, 1986; Roediger, 1984a) have argued that the long-term declarative knowledge system is most parsimoniously described as a single system of propositions, some of which represent semantic knowledge and some of which represent episodic knowledge about personal experiences.

For example, Hintzman (1984) contends that the primary difference between the episodic and semantic systems as described by Tulving is that ''episodic memory represents temporally and spatially localized events, while semantic memory represents the abstract or generic information commonly called concepts'' (p. 241). However, Hintzman argues that semantic memory can be generated from episodic memory traces, thus making the assumption of the existence of separate episodic and semantic systems unnecessary. Specifically, he suggests that in responding to a semantic-memory question such as *What is an elephant?* various episodic memory traces involving *elephant* would be activated, and all would contain specific temporal and spatial information concerning a specific episode involving *elephant*. However, he postulates a model in which all such temporal and spatial information that is not common to all of the activated traces would be canceled out, leaving abstract conceptual information common to all of the activated traces as the basis for answering the question.

Furthermore, McKoon, Ratcliff, and Dell (1986) argue that the distinction between episodic and semantic knowledge based on temporal versus conceptual coding is ultimately untestable because episodic memories are, by definition, temporal. In addition, McKoon and colleagues contend, the distinction will be impossible to assess as long as it is unclear what sort of semantic information is included in the episodic trace of an event. They also argue that Tulving's suggestion that episodic memories are more subject to forgetting is difficult to test because of the difficulty in ensuring that ''episodic and semantic memories are equated on dimensions such as degree of learning, difficulty of material, and so on'' (p. 297). They also cite evidence from amnesic patients suggesting similar rates of forgetting for newly learned episodic and semantic information (e.g., Zola-Morgan, Cohen, & Squire, 1983; Cohen, 1984).

What are the major arguments used by critics in advocating that long-term memory be viewed as a single, unitary store rather than as separate semantic and episodic systems?

Alternative Interpretations of Dissociation Effects

A number of the critics of the episodic-semantic distinction have also argued that the dissociation effects emphasized by Tulving are not convincing evidence for the existence of separate systems. Hintzman (1984) notes that evidence that one independent variable affects two tasks differently means only that the two tasks involve at least one different underlying process but that such an assumption does not justify the claim of two different memory systems. Similarly, Kihlstrom (1984), Klatzky (1984), Roediger (1984a), and Wolters (1984) argue that one can explain why certain variables affect semantic and episodic tasks differently simply by assuming that episodic and semantic memories differ in the type of information contained in the memory trace.

No assumption of separate memory systems is required to explain the dissociation effects. For example, take the Jacoby and Dallas (1981) experiment cited by Tulving and discussed above in which it was found that the level at which the words were processed in the first part of the study affected performance on the following episodic recognition task but did not affect performance on the following semantic identification task. Kihlstrom, Klatzky, Roediger, and Wolters argue that this dissociation can be explained by assuming that the type of judgment made about each word in the first part of the experiment affected recognition-relevant episodic information but did not affect naming-relevant semantic information included in the memory representation. That is, whether one judges if the word *acrobat* is written in capital letters or not or would fit in the sentence *He undressed the* _____ may affect the episodic contextual information included in the memory representation of *acrobat*, and such information may in turn affect one's ability to recognize subsequently that *acrobat* was one of the words processed in the first part of the study. However, regardless of whether one makes the capital letter judgment or the sentence judgment, the memory representation of *acrobat* is likely to contain the semantic information necessary for naming the word. Thus semantic identification would not be affected by the type of processing to which the word was subjected in the first part of the study.

Alternative Interpretation of Amnesics' Performance

Baddeley (1984) also challenges Tulving's interpretation of amnesics' performance in terms of the episodic-semantic distinction. The Warrington and Weiskrantz (1974) findings that amnesics performed significantly more poorly than normals on an episodic recognition test but just as well as normals on a word-fragment completion task is better interpreted, Baddeley argues, in terms of the distinction between declarative and procedural knowledge. Specifically, Baddeley argues that the word-fragment completion task should not be conceptualized as a semantic memory task. Rather, the word completion task is better described as a test of procedural knowledge involved in retrieving items from the lexicon, or mental dictionary.

Thus the Warrington and Weiskrantz results are better interpreted, Baddeley claims, in terms of amnesics being impaired in their ability to encode new declarative knowledge while remaining unimpaired in the performance of tasks tapping primarily procedural knowledge, consistent with other evidence cited earlier in this chapter in the discussion of the procedural-declarative distinction. Baddeley's description of additional evidence in support of this position will be considered later in the discussion of amnesia in Chapter 11.

How are critics' interpretations of dissociation effects different from Tulving's interpretation?

Status of the Debate

Despite these criticisms of Tulving's arguments for distinct episodic and semantic long-term memory systems, many of the critics admit that the distinction does have value in guiding and furthering investigation of how information is represented in a unitary long-term store of declarative knowledge. As Kihlstrom (1984) observes, the distinction provides ''a useful means of categorizing the *kinds* [emphasis added] of information stored in memory and supplied by queries to the memory system, and the kinds of retrieval tasks to which the rememberer can be put'' (p. 244).

McKoon, Ratcliff, and Dell (1986) suggest that the semantic-episodic distinction must be made more specific if it is to become a useful theoretical framework. They conclude by observing:

> *We do not think that more progress will be made toward an understanding of memory for semantic and episodic information until more theoretical work is done. The*

> *episodic-semantic distinction is an interesting idea that has had much heuristic value for interpreting and generating data over the past 14 years. Now it needs theoretical development. (p. 304)*

In his responses to these criticisms, Tulving (1984, 1985, 1986a, 1986b) has been remarkably muted. In fact, he has accepted a number of the criticisms as valid. In doing so, in 1984 he proposed a modification of his episodic-semantic distinction in which episodic memory is viewed as a "functionally distinct system that grows out of but remains embedded in semantic memory" (p. 259). On this view, episodic memory is seen as a subsystem of semantic memory. Although Tulving contends that conceptualization may make it possible to answer some of the criticisms leveled against the distinction, such a reformulation is likely to be seen by critics as a major retreat. In fact, McKoon and colleagues (1986) have already argued that, in proposing the embeddedness concept, Tulving has moved closer to the single-store position.

The situation has been further complicated by Tulving's (1985) suggestion that semantic memory should, in turn, be viewed as a specialized subsystem within the procedural memory system. Thus, in place of the classification scheme for long-term memory shown in Figure 7–5, Tulving is now proposing a scheme of the type illustrated in Figure 7–7. Furthermore, Tulving (1985; Hayman & Tulving, 1989) has also suggested that an additional memory system, which he has dubbed the **QM system** (for Question Mark or Quasi-Memory system), may exist as a precursor to the episodic memory system. Tulving has specifically proposed the QM system in order to account for priming effects that cannot be easily interpreted in terms of either the distinction between procedural and declarative knowledge or the distinction between semantic and episodic declarative knowledge.

How has Tulving responded to criticisms of the semantic-episodic distinction?

The Principle of Encoding Specificity

Thomson and Tulving's (1970) Study of Retrieval Cue Effectiveness

Tulving's argument for the distinction between episodic and semantic memory systems arose in part out of his demonstration of an episodic memory phenomenon that he and colleagues dubbed encoding specificity. In 1970, Thomson and Tulving reported three experiments in

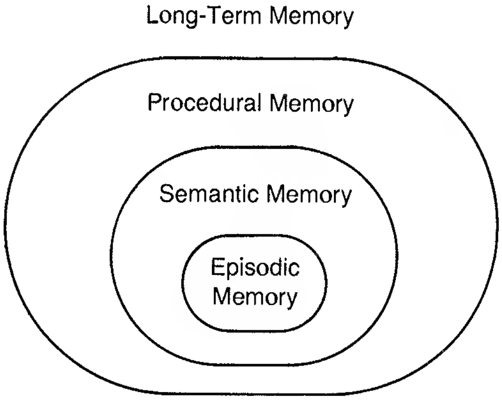

FIGURE 7–7 Tulving's classification of long-term memory systems in which semantic memory is a specialized subsystem within procedural memory and episodic memory is a specialized subsystem within semantic memory.

which they studied the effectiveness of retrieval cues in a situation involving the learning of three lists of words. Each list consisted of 24 cue-target word pairs, such as sky-BLUE and swift-GO. Thus some of the cue words were strongly associated, on the basis of previous experience, with the paired target word, and some were not. The selection of strongly and weakly associated cues was based on responses of other subjects to the cue words on a free association test. Strongly associated cues were those that tended with a high probability to elicit the target word on a free association test, whereas weakly associated cues were those that tended to elicit the target word with only a low probability.

Following each of the first two lists, subjects were asked to recall as many of the target words as they could in response to the provided cue words. However, following the third list, some of the cue words presented on the test had not been presented during study. Of these new cue words, some were strong associates of target words from the list, and others were weak associates of target words. Thus each recall cue on the test of memory for the third list represented one of four encoding-retrieval conditions:

> *strong/strong* → The cue provided was a strong associate of the target word and had been present during the study of the list.
>
> *strong/weak* → The cue provided was a weak associate of the target word and had not been present during the study of the list; instead, at study, the target word had been paired with a strongly associated cue.
>
> *weak/weak* → The cue provided was a weak associate of the target word and had been present during the study of the list.
>
> *weak/strong* → The cue provided was a strong associate of the target word and had not been present during the study of the list; instead, at study, the target word had been paired with a weakly associated cue.

Thomson and Tulving were particularly interested in whether strongly associated cues would be the best retrieval prompts regardless of whether or not they had been present at the time of study. Table 7–4 shows the results from their experiment.

Clearly, the strongly associated cue was not universally a better retrieval prompt. Weakly associated cues that were present at the time of encoding were better retrieval prompts than were strongly associated cues that were not present at the time of encoding. These results led Tulving and associates to propose the original version of the **encoding specificity principle.** That principle stipulated that effective retrieval cues are those that contain information that was included in the original encoding of the item or event. That is, the relationship between the memory trace and the retrieval cue is emphasized. Remember-

TABLE 7–4 Percentage of Items Recalled in the Thomson and Tulving (1970) Study as a Function of Encoding/Retrieval Condition

	Cue Present at Encoding	
Cue Present at Retrieval	*Strong Associate*	*Weak Associate*
Strong associate	83	33
Weak associate	3.5	73

ing is based on a match between information contained in the retrieval cue and information contained in the memory trace. Thus, the effectiveness of a retrieval cue cannot be predicted in the absence of information about the conditions of encoding.

What were the most important findings of Thomson and Tulving's (1970) investigations of retrieval cue effectiveness?

Implications of the Encoding Specificity Findings

Such a notion may seem now intuitively obvious, but at the time it was proposed, the principle challenged a number of popularly held assumptions, including what Tulving and associates called the **associative continuity assumption.** This assumption involves the notion that the strength of association between items in memory is a function of the number of times the items have been encoded together. Tulving and associates argued that the concept of strength of association is meaningless to the extent that it is based on the assumption that most items in memory have a unitary representation that is simply updated with each subsequent occurrence of the item.

Instead, Tulving and associates (e.g., Tulving & Thomson, 1971, 1973) argue, each occurrence of an item results in a unique memory representation of the item that may or may not include a lot of information about the item's past associations. The contents of the memory representation of the item will be determined by the conditions under which encoding takes place. Thus it is meaningless to talk about certain items being more memorable than others or certain study activities being more effective than others without considering the conditions under which retrieval will take place.

For example, as was discussed in Chapter 6, semantic processing of to-be-remembered information does not invariably lead to superior retention of the information. If at the time of retrieval, rhyme cues are presented to prompt memory, having processed the information semantically at encoding may produce performance inferior to that exhibited after having processed the information phonemically at encoding because the memory trace of the event will be less rich in phonemic information likely to overlap with that provided in the retrieval cue. The implications of such a view of memory for the traditional distinction between recall and recognition and for other issues associated with memory retrieval will be discussed in Chapter 9.

In his review of research generated by the encoding specificity principle, Tulving (1983, 1984) notes that experiments designed to test the principle must simultaneously manipulate conditions of encoding and retrieval in order to assess the level of performance exhibited when the retrieval environment is and is not compatible with the encoding environment. Since the proposal of the principle, a large number of such studies have been conducted, and a large percentage of these have found the expected crossover interaction in which performance is a joint function of encoding and retrieval conditions.

A particular type of encoding condition is effective only to the extent that retrieval conditions prompt the use of information likely to have been encoded. One such encoding-retrieval experiment was that of Morris, Bransford, and Franks (1977), referred to in an earlier paragraph and described in more detail in Chapter 6. When the retrieval task involved a rhyming recognition test, phonemic processing of the words at encoding resulted in superior performance. When the retrieval task involved a standard recognition test, semantic processing of the words at encoding resulted in superior performance.

How is the encoding specificity principle consistent with the episodic-semantic distinction?

State-Dependent Memory

Investigations of other more exotic memory phenomena can be also be viewed as examples of encoding/retrieval experiments, and the results can be interpreted in terms of the encoding specificity principle. One of these phenomena is that of **state-dependent memory.** Most generally, this concept refers to findings that information learned in a particular physiological state is best recalled when one is in that same physiological state. Physiological state has been manipulated through the use of drugs, including alcohol, marijuana, amphetamines, barbiturates, and Parkinson's disease medications (e.g., Adams, Castro, & Clark, 1974; Bustamante, Jordán, Vila, González, & Insua, 1970; Goodwin, Powell, Bremer, Hoine, & Stern, 1969; Huber, Shulman, Paulson, & Shuttleworth, 1989; Petersen, 1977; Weingartner, Eich, & Allen, 1976).

In a typical study by Eich, Weingartner, Stillman, and Gillin (1975), half of the subjects studied a list of words after smoking a cigarette containing active marijuana, and half of the subjects studied the list after smoking a cigarette that contained placebo material. Then, prior to testing, half of the subjects in each of these two encoding conditions smoked a marijuana cigarette and half smoked a placebo cigarette. When the subjects were asked to free recall the words studied, the researchers found a significant interaction of encoding and retrieval condition. Those subjects in the marijuana-marijuana condition recalled significantly more words than those subjects in the marijuana-placebo condition, whereas those subjects in the placebo-placebo condition recalled more words than those subjects in the placebo-marijuana condition, although the difference was not significant.

Eich (1980) argues that such effects are directly interpretable in terms of the encoding specificity principle. If one assumes that the memory representation of an item or an event includes information about the pharmacological state of the person at the time of encoding, then the individual's pharmacological state at the time of retrieval would represent an additional source of cues. When the pharmacological cues at retrieval match those that were present at encoding, successful retrieval is enhanced.

Mood Effects. Mood effects on memory are also interpretable as an instance of state-dependent learning. Bower (1981), for example, has manipulated the mood of subjects through the use of hypnosis. Subjects encouraged to adopt a sad mood prior to studying a list of words showed better recall of the words when they were also sad at retrieval than when they were happy at retrieval. Conversely, subjects encouraged to adopt a happy mood prior to encoding the words showed better recall of the words when they were also happy at retrieval than when they were sad at retrieval. Just as one can assume that information about a person's drug state can be included in the memory representation of an item or event, one can assume that information about a person's mood can be included in the memory representation. Thus a mood state at retrieval that matches that present at encoding will facilitate retrieval by providing additional cues for locating the target memory trace.

How can drug and mood effects on memory be viewed as examples of state-dependent memory?

Generality of the Effect. It is important to note, however, that findings of state-dependent learning are not universal. Eich (1977, 1980) has pointed out in two large-scale surveys of research on the topic that at least half of the published studies of this issue have not found evidence of state-dependent learning. Eich's (1980) analysis of these conflicting findings have led him to propose that the state-dependent effect is only likely to be found when memory for the target information is tested in the absence of clearly identifiable and observable cues.

For example, in the Eich and colleagues' (1975) study described above, the state-dependent effect was not found when recall of the words was cued with the names of the categories to which the words in the list belonged. Likewise, in a later study also involving marijuana, Eich and Birnbaum (1982) found that matching pharmacological state at encoding and retrieval facilitated the uncued recall of category names from a to-be-remembered list containing both category names and exemplars of the categories but had no effect on the recall of category members in response to the category names. Such findings suggest that physiological cues may be relatively weak in their effects on memory compared to linguistic or conceptual information likely to be included in the memory trace of target information.

In a review of research on mood-dependent memory, Ucros (1989) also found a number of studies in which state-dependent effects were not obtained. Her analysis of the studies suggested that variables such as subjects' commitment to the experiment and the complexity of the experimental environment may influence the emergence of the state-dependent effect.

What evidence suggests that physiological cues involved in state-dependent learning may be relatively weak in their effects on memory?

Environmental Reinstatement Effect

Also interpretable within the encoding specificity framework is the **environmental reinstatement effect.** This phenomenon refers to the finding that information learned in a particular physical environment is best remembered in that same physical environment. With regard to the example of Alan presented at the beginning of the chapter, the environmental reinstatement effect suggests that Alan's performance on his upcoming biology exam would be enhanced by his studying for the exam in the same environment in which he is to take the exam.

In an experimental test of the environmental reinstatement effect, Godden and Baddeley (1975) had scuba divers learn lists of words either under water or out of the water. Then, half of each group were asked to recall the words in the same environment in which they had studied, and half were asked to recall the words in the other environment. A significant interaction was found. Those who studied the words under water recalled significantly more words when tested under water, whereas those who studied words out of the water recalled significantly more when tested out of the water. Consistent with the encoding specificity principle, these results suggest that environmental stimuli present at the time of study can become a part of the memory trace for the material and thus acquire the power to cue retrieval of the information from memory.

How can the environmental reinstatement effect be viewed as an example of encoding specificity?

Smith's Demonstrations of the Environmental Reinstatement Effect. In a series of experiments, Smith and colleagues (Smith, 1979, 1982, 1984, 1985, 1986; Smith, Glenberg, & Bjork, 1978) reported evidence of an environmental reinstatement effect in situations involving much less dramatic manipulations of environment. In these experiments, Smith used different rooms in university buildings as his experimental contexts. In general, Smith has found that memory for word lists is better when subjects are tested in the same room in which they studied the words.

In his experiments, Smith attempted to demonstrate that these findings are in fact a function of a match/mismatch of study and test environments and are not due to other factors. For example, to control for the effect of a general disruption between study and test, subjects in both the same- and different-context conditions have been required to move from the study environment to a waiting room before being taken to the room in which they are asked to recall the information. In addition, to control for the possibility that subjects in the different-context condition may do more poorly simply because they are unfamiliar with the test environment, Smith, in many of his experiments, familiarized subjects with the test environment prior to the test phase of the study by having them make drawings of the room.

✎ *What controls did Smith employ in his demonstrations of the environmental reinstatement effect?*

Lack of Evidence for the Environmental Reinstatement Effect. However, the environmental reinstatement effect no longer appears to be as reliable as Smith's program of research would appear to suggest. Eich (1985) found no environmental reinstatement effect for subjects asked to generate isolated images of the to-be-remembered words, but an environmental reinstatement effect was evidenced by subjects asked to create images of the to-be-remembered words that linked each word with some physical feature of the room context. The failure to find the environmental reinstatement effect for the isolated imagery condition led Eich to suggest that the environmental reinstatement effect may be much rarer than Smith's research would indicate. Furthermore, in a series of eight experiments, one of which represented an attempt to replicate one of Smith's (1979) original experiments, Fernandez and Glenberg (1985) failed to find a consistent environmental reinstatement effect. Finally, Wilhite (1991) has found in two experiments that subjects who studied and were tested in different rooms showed significantly better memory than subjects who were tested in the same room in which they studied.

Wilhite's results are noteworthy because he employed many of the same controls used by Smith in his research and because he used prose materials as well as word lists as the to-be-remembered materials. In interpreting his results, Wilhite suggests that reinstating environmental context at the time of test may not invariably facilitate memory performance because environmental cues may be subject to overloading just as verbal cues are.

For example, it has been found that verbal cues become less and less effective as they become associated with increasing numbers of to-be-remembered items (Eich, 1985; Watkins & Watkins, 1975). Thus, Wilhite argues, under some conditions environmental cues may lose their effectiveness by becoming associated with multiple target items. As a result, the performance of same-context subjects may suffer, relative to the performance of different-context subjects, because overloaded environmental cues may interfere with alternative retrieval strategies involving cues such as the items' position in the list.

Saufley, Otaka, and Bavaresco (1985) sought evidence of the environmental reinstatement effect in a study designed to determine whether changing the classroom environment at the time of an examination alters contextual associations sufficiently to lower students' examination performance significantly. Across the seven courses, a total of 21 comparisons were made between the examination performance of those students tested in the usual lecture room and the examination performance of those students tested in a different classroom.

None of the comparisons revealed a significant difference in the performance of the same- and different-context groups, and there was no evidence of a trend favoring the same-context group. Saufley and colleagues argue that the total lack of an environmental reinstatement effect in this study was almost certainly, at least in part, a function of the degree to which learning in an academic course is decontextualized by the use of a variety of materials, such as lecture notes and textbooks, that permit study and learning outside the lecture hall.

What sorts of findings challenge the reliability of the environmental reinstatement effect?

Further Evidence for the Environmental Reinstatement Effect. In an investigation of how the type of encoding performed on the to-be-remembered information might influence the environmental reinstatement effect, McDaniel, Anderson, Einstein, and O'Halloran (1989) performed five experiments involving 38 separate tests of the environmental context effect. Of the 38 comparisons, only 8 showed a statistically significant environmental reinstatement effect. Thus the results of this study are, in general, consistent with the view that environmental context effects are far from overwhelming, perhaps because people's experiences have taught them that the room in which information is encoded is not a reliable cue for its recall (Wickens, 1987).

However, based on their analysis of the limited number of cases in which the reinstatement effect was found, McDaniel and colleagues argue that reliance on environmental context as a source of retrieval cues, and hence the emergence of the environmental reinstatement effect, is most likely in situations in which other potentially more useful retrieval cues are not available or are not employed. For example, they found that memory for common sentences was more affected by reinstating environmental context than was memory for bizarre sentences. McDaniel and colleagues suggest that this finding emerged because a variety of nonenvironmental cues for retrieving the bizarre sentences may be generated as a result of the more elaborate or distinctive encoding afforded the bizarre sentences (Einstein & McDaniel, 1987; Hirshman, Whelly, & Palij, 1989). This interpretation by McDaniel and colleagues is consistent with the failure to find an environmental reinstatement effect in the naturalistic classroom study by Saufley and colleagues (1985) described above. The test questions used in the college courses included in that study may have provided sufficient retrieval cues so as to make contextual associations involving the room environment relatively unimportant.

The conflicting pattern of results regarding the environmental reinstatement effect illustrates one of the weaknesses of the encoding specificity principle. It is far from obvious how one can, with any degree of certainty, predict in advance what sorts of information will be included in the memory representation of the event and will, therefore, function as effective retrieval prompts. In this regard, the research by McDaniels and colleagues represents a promising direction for future investigation of the environmental reinstatement effect. Rather than focusing on whether the environmental reinstatement effect is reliable, researchers need to try to establish the boundary conditions for the effect by investigating the conditions under which information about the physical environment tends to be included in the memory representation of items and tends to prompt memory effectively.

Under what general conditions is the environmental reinstatement effect most likely to emerge, according to McDaniel, Anderson, Einstein, and O'Halloran (1989)?

CONCLUDING REMARKS: The Maltese Cross Model Revisited

It would be useful at this point to consider how the various issues and distinctions presented in this chapter can be related to Broadbent's Maltese cross model of memory presented in Chapter 6. The distinction between declarative and procedural knowledge is generally consistent with Broadbent's distinction between the long-term store and the processing system. Broadbent proposed the distinction between the long-term associative store and the processing system in part in order to make clear the distinction between the representation of information and the processing of information within the memory system. This same representation-processing distinction underlies Anderson's description of declarative and procedural knowledge.

Although Broadbent has not dealt with procedural knowledge in the formalized way that Anderson has, his description of the processing system is compatible with Anderson's production-based characterization of procedural knowledge. That is, it would certainly appear possible to represent the duties assigned to the processing system in the Maltese cross model as a system of productions. For example, Broadbent argues that the processing system is responsible for the transfer of information from one memory store to another and that transfer operations involve transforming the information into a form that can be handled by the receiving store. Such operations could be represented as condition-action rules of the type that constitute the production systems in Anderson's description of procedural knowledge.

The distinction between episodic and semantic memory can also potentially be integrated into the Maltese cross model's description of the long-term associative store and the processing system. For example, it would certainly be possible to argue that the long-term associative store is composed of distinct episodic and semantic components, although Broadbent has not yet done so. The important point to note here is that the Maltese cross model provides a potentially useful general framework within which a number of concepts and distinctions regarding long-term memory can be incorporated. What remains to be determined is which of the concepts and distinctions presented in this chapter will prove to be sufficiently useful to warrant inclusion in such a general model of long-term memory.